BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Range Safety System Operations During Saturn V Launch Countdowns Case 320

DATE: August 14, 1968

FROM: G. J. McPherson, Jr.

ABSTRACT

During recent planning activities at KSC, two areas of significance have received considerable attention. Both are directly concerned with launch-crew or flight-crew safety and will affect the length of Saturn V launch countdown and scrub-turnaround operations. The two areas (S&A device connection/disconnection and the final LV/Range command checks), although separated operationally by time, are directly related to each other both in circuitry and hardware.

Background information including the most recent KSC activities are discussed to familiarize the reader with previous criteria and current considerations/decisions. A description of the related hardware, circuitry, ordnance characteristics, and operations are included.

An assessment of the hazards involved with both operations along with the electrical, mechanical and procedural safeguards implemented resulted in the following recommendations:

S&A Device Connection/Disconnection

1. That S&A device connection/disconnection be allowed with the MSS and personnel at the launch pad.

2. That the personnel clearance requirements presently advocated by KSC Safety (internal to the SV below the CSM) be maintained to prevent interference with or distraction to the ordnance crews.

3. That KSC and/or MSFC give due consideration to the items discussed under conclusions 7 through 11.

Final LV/Range Command Checks

1. That the last DRSCR check after final decoder/command receiver power-up be retained for final FTS launch confidence.

(NASA-CR-73533) RANGE SAFETY SYSTEM OPERATIONS DURING SATURN 5 LAUNCH COUNTDOWNS (Bellcomm, Inc.) 52 p
N79-72003
Unclas
00/14 11318

Abstract

2. That decoder/command receiver power-up with S&A device ordnance connected, not be considered a particularly hazardous operation and pad access for the SC closeout crew (or any justified crew) be considered based on need and other operational alternatives. Obviously, if clearing the launch pad does not penalize the operation adversely, it would be desirable to continue to do so.

3. That the earlier DRSCR check be implemented and retained (at least for AS-503/LM-3/CSM 103), for the reasons stated in conclusion no. 4, until such time that experience indicates that the confidence level would not be significantly decreased by its elimination.

4. That as long as the early DRSCR check is retained, it not be considered particularly hazardous and access be allowed similar to item 2 above.

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Range Safety System Operations During Saturn V Launch Countdowns Case 320

DATE: August 14, 1968

FROM: G. J. McPherson, Jr.

MEMORANDUM FOR FILE

1.0 INTRODUCTION

During recent planning activities at KSC, two areas of significance have received considerable attention. Both are directly concerned with launch-crew or flight-crew safety and will affect the length of Saturn V launch countdown and scrub-turnaround operations. The two areas (S&A device connection/disconnection and the final LV/Range command checks), although separated operationally by time, are directly related to each other both in circuitry and hardware.

Background information including the most recent KSC activities are discussed to familiarize the reader with previous criteria and current considerations/decisions. A description of the related hardware, circuitry, ordnance characteristics, and operations are included as Addendums I through IV. A list of abbreviations can be found in Table 3.

2.0 BACKGROUND INFORMATION

Safety and Arming (S&A) Device Connection/Disconnection

The original criteria established for connection/disconnection of the S&A devices on LC-39 required clearance of all personnel (except those directly involved in the ordnance operation) from the LUT and immediate pad area. As a result of the inherent MSS/primary damper 35-foot constraint,* KSC Safety required that the MSS be at the imaginary 35-foot point and moving towards its park-site prior to S&A connection. It was conversely required that the MSS remain outside the 35-foot point until S&A disconnection was completed.

The AS-501 CDDT revealed that for unmanned Saturn V countdowns where SC closeout is performed prior to LV cryogenic loading, a significant amount of serial time would be required unless SC closeout operations could be performed concurrent with LV S&A connection. KSC Safety agreed to allow the concurrent

---

*Because of a physical interference between the primary damper arm and the MSS, the damper cannot be lowered or raised unless the MSS is some minimum distance away from its pad position. Thirty-five feet was adopted as a good "talking" distance for documentation purposes.

operations with a restriction on the size of the SC closeout crew. This plan was implemented successfully on the AS-501 launch countdown and subsequently also for the AS-502 countdowns.

LV/Range Command Checks

During the AS-501 launch countdown, the Digital Range Safety Command Receiver (DRSCR) checks were performed as follows:

a. open and closed-loop from the Range with the pulse sensor units prior to S&A connection -- ≈T-14 1/2 hours

b. closed-loop from the Range with the S&A's connected -- ≈T-36 minutes

On AS-502, the same checks were performed at about T-16 1/2 hours and T-33 minutes, respectively.

The early checks are an end-to-end test. The Exploding Bridgewire (EBW) Firing Unit (F/U) is actually charged and then triggered to discharge through a pulse sensor unit which is connected in place of the EBW detonator. The late checks (closed-loop) involve charging the EBW F/U and discharging it through its built-in bleeder circuitry; also, verifying the Destruct command (blocked from reaching the now-connected EBW detonator) with telemetry and the Electrical Support Equipment (ESE).

Related Activities

Subsequent to the AS-501 launch, the author conducted a study* of the Mobile Service Structure (MSS) with respect to how it constrains LC-39 operations. At that time, KSC Safety interpreted their S&A clearance criteria (MSS at least 35 feet from SV) as being personnel -- not hardware oriented. Based on this interpretation, the referenced study revealed that significant benefits to Saturn V scrub-turnaround operations would be realized from an earlier return of the MSS, prior to S&A ordnance operations. That technique was presented to the Saturn V Countdown Working Group (CDWG) and subsequently agreed upon by the members which included KSC Safety. The CDWG, as part of its scrub-turnaround planning activity, adopted the technique and determined that it would be implemented in all Saturn V scrub-turnaround planning subsequent to AS-502.

---

*Bellcomm Technical Memorandum TM 68-2032-1, "Analysis of Operations and Constraints Associated with the Mobile Service Structure (MSS) at Launch Complex 39," Case 320, dated May 8, 1968, by G. J. McPherson.

3.0 RECENT ACTIVITIES

S&A Connection/Disconnection

Subsequent to the launch of AS-502, LVO suggested that the CDWG consider a similar technique during the launch countdown, that is, retain the MSS at the launch pad later in the countdown until after completion of S&A ordnance connection activities. This approach would provide significant benefits to both LVO and SCO in the form of a shorter launch countdown and SV access via the MSS closer to T-0. During the ensuing discussions within the CDWG, it was decided that consideration should also be given to relaxing personnel clearance requirements during S&A ordnance operations. It was the concensus of the group that sufficient experience had been gained during Saturn I, Saturn IB and the two Saturn V launches to warrant reassessment of the ordnance operation and associated clearance requirements for both the LUT and MSS. The CDWG chairman requested that KSC Safety review the S&A ordnance operations, its built-in safeguards, and furnish the CDWG with their assessment.

At the June 10, 1968, CDWG meeting, the KSC Safety representative stated that their position concerning the S&A ordnance operations remained basically unchanged, and in fact, were now concerned about "risking the only MSS" during either launch countdown or scrub-turnaround operations relative to S&A connection/disconnection. Since this was in reality a regression from the previously agreed upon modus operandi (early return of MSS during scrub-turnaround activities), and was admittedly based on precedent and not a technical reassessment of the operation, the CDWG chairman reiterated his request for a comprehensive KSC Safety review of the S&A ordnance operations and reemphasized the group's concern and interest. KSC Safety agreed to reassess the S&A ordnance operation relative to both hardware and personnel hazard. It was at this time that the author decided an independent assessment was warranted.

DRSCR Checks

The AS-205 CDWG addressed the problems of when to perform the final DRSCR checks and how to integrate them into the first Apollo manned countdown. Since the flight crew would now be on board at the time the final DRSCR checks were previously accomplished, SCO suggest that the checks be accomplished subsequent to LV cryogenic loading, but prior to closeout crew and flight crew clearance to the pad. After considerable discussion within the group and a presentation by representatives of the Range Safety Office, it was established that a Range Safety requirement existed to perform the checks subsequent to final receiver power-up. This along with the necessity to power-down the receivers, reestablished the requirement for the final DRSCR check at around T-30 minutes.

To prevent closeout crew exposure and also to provide the flight crew an abort capability, it was decided to accomplish the final check after the closeout crew had departed the pad, the Apollo Access Arm had been retracted (to its 12° park position), and the SC pyro buses were armed. SCO then suggested that the early test be retained as added confidence. The CDWG agreed with the merits of the early test.

When this approach was presented to the Saturn V CDWG for incorporation in AS-503 countdown planning, considerably more discussion was in evidence as to the actual level of hazard involved to either the closeout crew or the flight crew. The general concensus of the CDWG indicated that receiver power-up and DRSCR checks with the ordnance connected was not as hazardous as originally thought and should be reassessed for possible relaxation of clearance requirements.

No specific action item was assigned since adopting an approach similar to the AS-205 decision was feasible although it would add some serial countdown time.

4.0 AUTHOR'S INTEREST

As a working member of the CDWG and being aware of the impact both decisions will have on not only all future Saturn V launch countdowns, but also the impact it will have on KSC's ability to achieve the much sought-after 44-hour scrub-turnaround capability, the author has endeavored to accumulate data which would allow an independent assessment. The data would also provide a basis for subsequent discussions within the CDWG.

Subsequent to the accumulation of data, the author was informed that KSC Safety had completed their assessment and indicated their receptiveness to a relaxation of clearance requirements during S&A ordnance operations. Their revised criteria, which will be implemented as a revision to the KSC Ground Safety Plan, will reportedly allow performance of concurrent work external to the SV from both the LUT and MSS but will require clearance of all personnel (except those directly involved with the ordnance operation) from within the SV (except the CSM). Since this revised KSC Safety position has yet to be authenticated in the proper documentation, and there would seem to be substantial merit in an independent assessment, the author has provided the nucleus of the accumulated data as well as some pertinent comments.

Also included is an assessment of the hazards involved with the final DRSCR checks. KSC Safety has not been requested to reassess this operation as a specific item at this time.

5.0 HARDWARE DESCRIPTION

A very general description of the hardware associated with the PDS has been included as Addendum I for those unfamiliar with the total system.

6.0 CIRCUITRY DESCRIPTION

A fairly complete description of the PDS circuitry (see Figure 2) has been included as Addendum II to aid the reader in understanding subsequent discussions within this memorandum.

7.0 ORDNANCE CHARACTERISTICS

Addendum III contains both the electrical characteristics of the EBW detonator and some of the inherent properties of the explosives used in the PDS.

The electrical characteristics of the EBW detonator greatly influence the degree of safety involved with S&A device connection/disconnection and are appropriately included.

The inherent properties of the explosives themselves do not have any direct bearing on either the S&A operations nor the DRSCR checks but are included to complement the description of the total PDS. This also allows a more comprehensive knowledge of the crew safety aspects of the PDS.

8.0 DESCRIPTION OF THE OPERATIONS

Since during both operations under review (S&A device connection/disconnection and final DRSCR checks), a variety of configurations, controls, and procedures could be implemented, a description of how the operations are proposed to be accomplished is included as Addendum IV.

9.0 CONCLUSIONS

S&A Device Connection/Disconnection

1. Adequate electrical safeguards exist to prevent EBW detonator initiation from single and double failure modes during both connection and disconnection.

2. Mechanical safeguarding is present in form of the S&A device which is designed to interrupt and confine the EBW detonator explosion when in the Safe position.

3. Adequate indicators are provided which allow remote monitoring of the primary functions of the PDS circuitry. Remote as well as local corrective actions are immediately available.

4. The likelihood of any <u>one</u> failure occurring during the actual 45 minute connection operation is very low. The correct combination of multiple failures occurring at the very time of S&A ordnance connection is even less likely.

5. The inadvertent firing of an EBW detonator into a "safed" S&A device does not present a hazard to informed personnel in the immediate area.

6. The PDS end-to-end functional checks prior to S&A ordnance connection provide adequate assurance that the components and circuitry (including safeguards) are valid.

7. The present stray voltage checks although adequate to protect the ordnance crews do not appear to provide for <u>reliable</u> detection of all possible voltage faults in the EBW F/U trigger input circuit. Admittedly, the type of failure, which would not be detected prior to the stray voltage checks and could be detected by an improved stray voltage check, is extremely unlikely; perhaps unlikely enough to warrant retention of the existing procedures.

8. Controlled switching and RF silence appear to be implemented* subsequent to the stray voltage checks which could leave some small uncertainty regarding the validity of the checks. Further investigation revealed that TI-2-13 and the individual stage procedures adequately call for RF silence and controlled switching prior to the stray voltage checks.

9. Neither the ESE nor LV circuitry provide protection against ESE faults (including the computer) from feeding back into the RSS controller circuitry (<u>Safe</u>, <u>ECO</u>, and <u>Destruct</u>). Such protection would protect the decoder components as well as eliminate the worry of ESE faults inadvertently activating potentially hazardous circuitry.

10. The LV countdown procedure nor some of the individual stage procedures specify maintaining the <u>S&A Device</u> control switch in the <u>SAFE</u> position during connection/disconnection operations. This would interrupt the <u>Arm</u> circuitry as well as provide for immediate safing should a spurious signal arm the S&A device.

---

*Reference 6.

11. The LV countdown procedure* specifies verification of particular RSO switch positions which affect interlock circuitry but does not specify verification of switches (ECO, DESTRUCT, SAFE, TIMER BYPASS) which affect the FTS. Since these directly influence mission success and crew safety, they would appear to be of at least equal importance with those currently specified in the procedure.

Final LV/Range Command Checks

1. Although most of the electrical safeguards enjoyed during the S&A connection/disconnection are necessarily eliminated during the DRSCR checks, adequate protection against single point failures remain in the form of the PD Block function and the absence of the Destruct signal during the ECO command check. Similarly, the PD Block function and absence of the ECO signal (no EBW F/U arm voltage) during the Destruct command check provide the double protection against EBW detonator firing.

2. Additionally, mechanical safeguarding is present in form of the S&A device which is designed to interrupt and confine the EBW detonator explosion when in the Safe position.

3. Powering-up the decoder and command receiver does not in itself create any potential hazard without multiple failures (within the decoder and ESE) occurring simultaneously. The decoder is designed to reset all address registers with power removed and only a properly coded message** will reopen this gate to an actual command.

4. Verifying the ECO and Destruct commands subsequent to final command receiver power-up will provide the desired launch confidence to the FTS. Performing the identical check just prior to the closeout crew proceeding to the launch pad does give some added confidence that the final check will not unduly jeopardize the flight crew but more significantly gives added confidence that system discrepancies will be detected prior to flight crew ingress and their exposure to the cabin flight atmosphere.

---

*Reference 6.

**A properly coded message is dependent upon the correct combinations of tones for each character in a word, the correct sequence of characters within each word, and timely receipt of each character. Failure to meet all of the foregoing criteria resets the decoder address register.

identical (functionally) to the Saturn V and LC-39. Since the last launch of the current generation of Saturn IB's is scheduled for the near future, recommendations have not been directed at that program. However, since someday AAP will be conducting launches with this same hardware and circuitry, consideration should be given to adopting (at least for AAP) any benefits derived from the accepted KSC Safety position (limited access during S&A connection/disconnection) and/or this study.

12.0 ACKNOWLEDGEMENTS

Numerous persons were contacted for answers to specific questions as well as for aid in acquiring additional information. Their cooperation and technical assistance is acknowledged.

Capt. J. Alonge	PAFB	USAF (Missile Safety)
A. A. Conway	MSFC	NASA (I-V-E)
A. Demco	KSC	NASA (LV-INS)
C. W. Dowling	KSC	NASA (LV-ENG)
A. H. Moore	KSC	NASA (TS-TSM
D. A. Roesch	KSC	DAC* (Struct/Mech Design)
J. B. Stulting	MSFC	NASA (R-ASTR-EAS)
Maj. R. Taylor	PAFB	USAF (Range Safety)

2032-GJM-sam

G. J. McPherson, Jr.

Attachments
Figures 1-4
Addendums I-IV
Tables 1-3

---

*DAC is the ordnance installation integrator for the Saturn V launch vehicle.

BELLCOMM, INC.

REFERENCES

1. Apollo/Saturn V Safety Circuits AS-503, The Boeing Company (BATC), March 4, 1968*

2. Apollo/Saturn V Safety Circuits Description AS-503, The Boeing Company (BATC), March 4, 1968*

3. Military Explosives, Department of the Air Force Technical Order, TO 11A-1-34, April 14, 1955

4. Explosive Ordnance Systems for the S-IVB Stage of the Saturn V Space Vehicle, DAC Report Number SM-47370, no date

5. Saturn V Composite Mechanical Schematic, 10M30531 Rev. G (MSFC), February 15, 1968

6. Launch Vehicle Operations for Support of Space Vehicle Countdown Demonstration Test and Launch Countdown AS-502, OCP V-20044 Basic (KSC), February 16, 1968

7. Astrionics System Handbook, Saturn Launch Vehicles, MSFC, August 1, 1965

8. Launch Vehicle Operations Technical Instruction, TI-2-13 (KSC), April 17, 1967

9. Specification for Exploding Bridgewire Firing Unit, 40M39515B (MSFC), April 20, 1965

10. Schematic Wiring Diagram for Firing Unit and Cable, 32401 Rev. U (General Laboratories Associates), September 9, 1966

11. Description of the Exploding Bridgewire Firing Unit, 40M39003C (MSFC), March 1, 1967

12. MSFC EBW F/U Test Data (Included within the body of the paper).

13. Apollo/Saturn V Ground Safety Plan LC-39 Vol. II, February 1, 1968

14. Exploding Bridgewire Detonator, Specification Control Drawing 7865742 Revision S (Douglas Aircraft Company), September 20, 1967

15. S-IVB Support and Preparation for Countdown Demonstration and Countdown, Vol. II, OCP V-20043 Basic (DAC), March 8, 1968

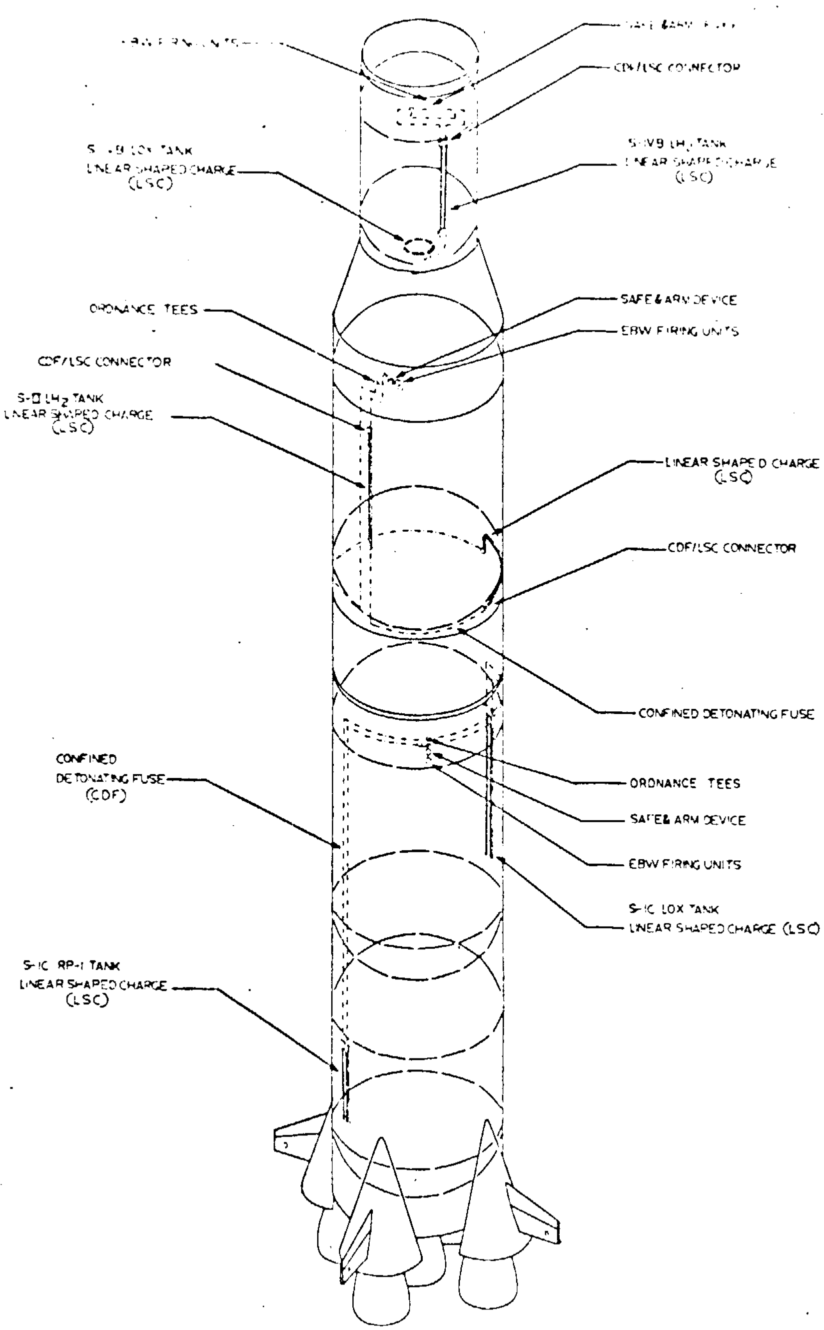
---

*Companion documents

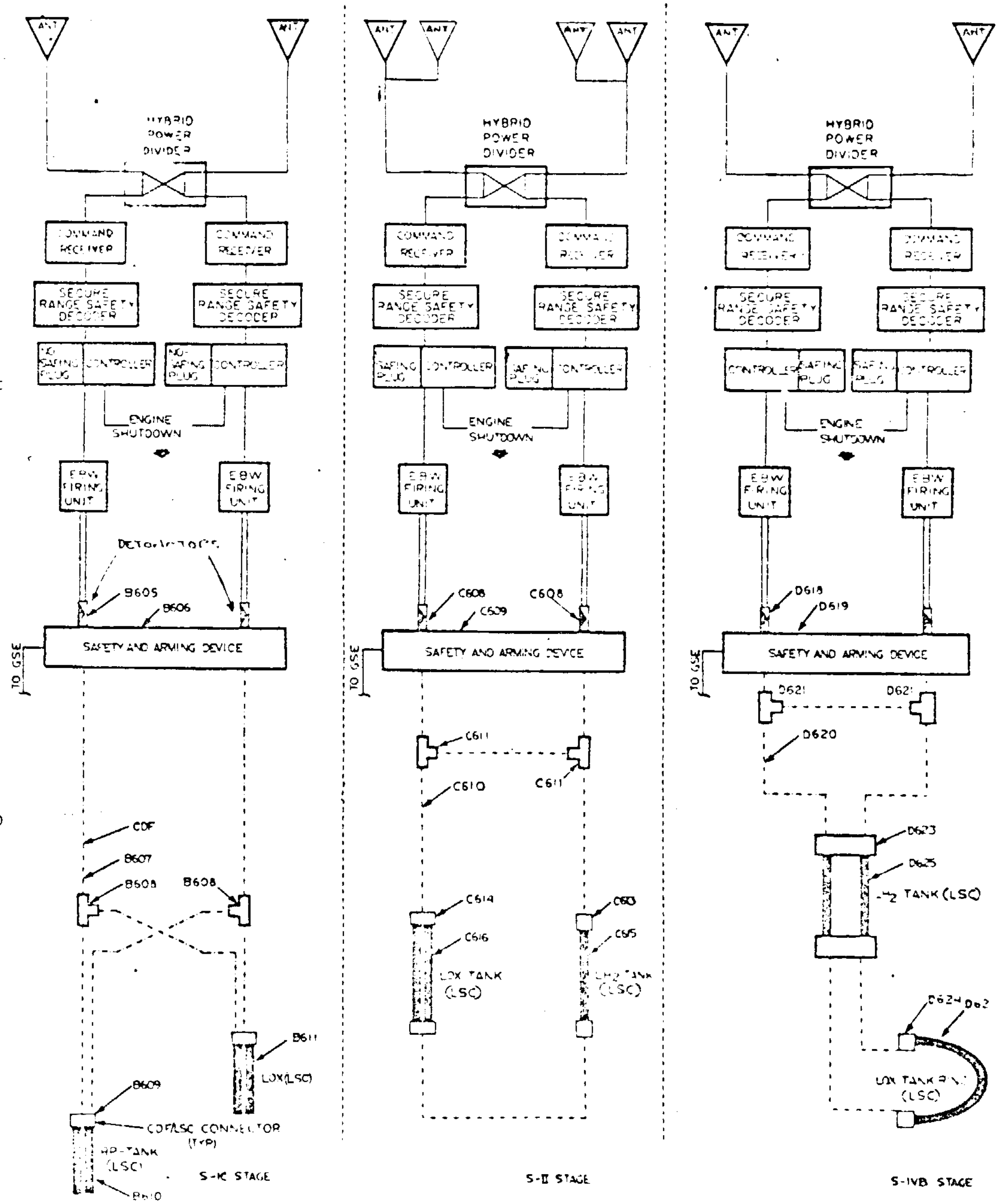
References

16. Ordnance Systems Saturn V Launch Vehicle, SE 005 003 2H (MSFC) - April 1, 1968.

17. Reliability Assessment of Saturn V Ordnance Items Including the Associated RF Command Subsystem Components, RA-P-110-68 (MSFC) - June 25, 1968.

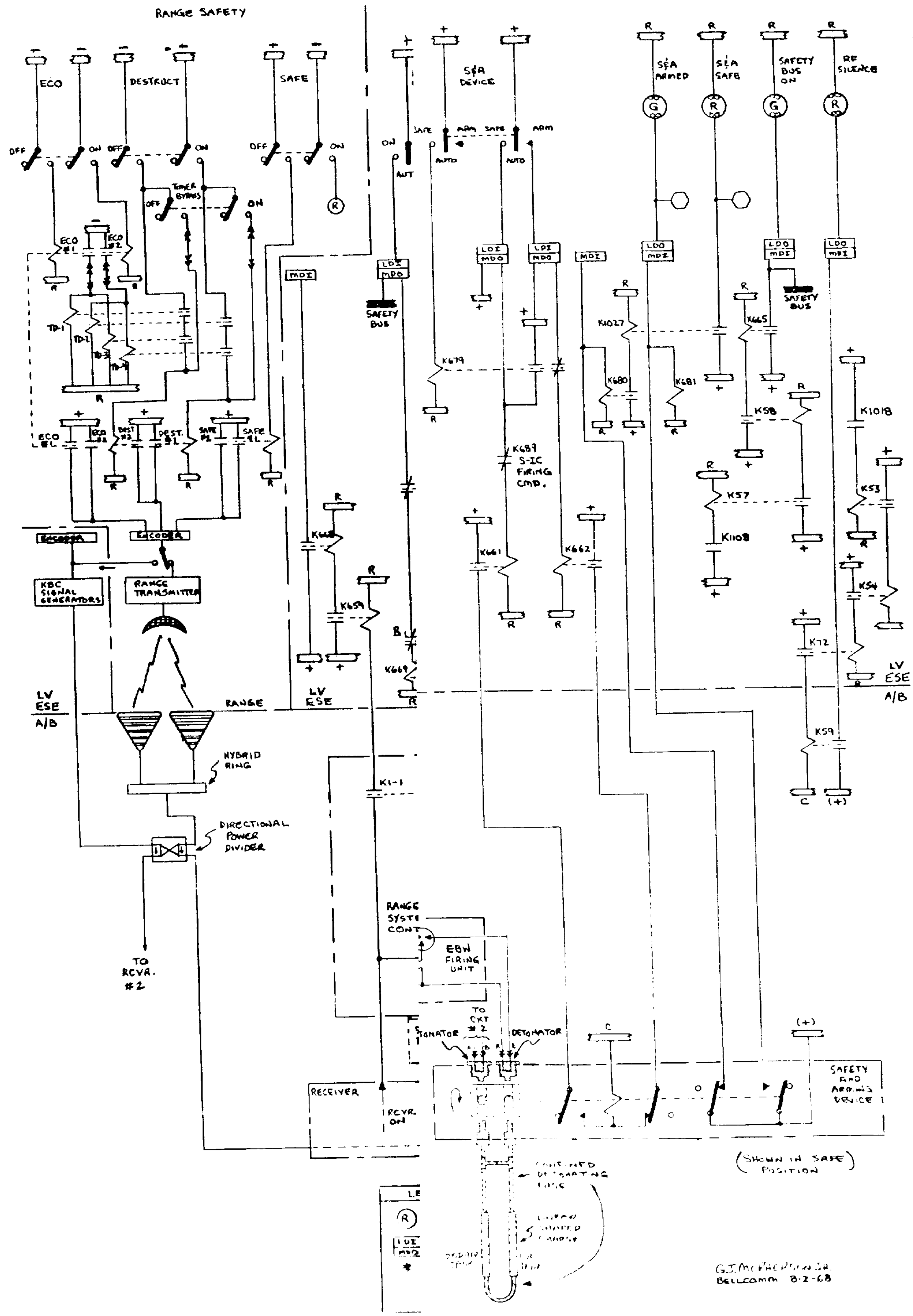


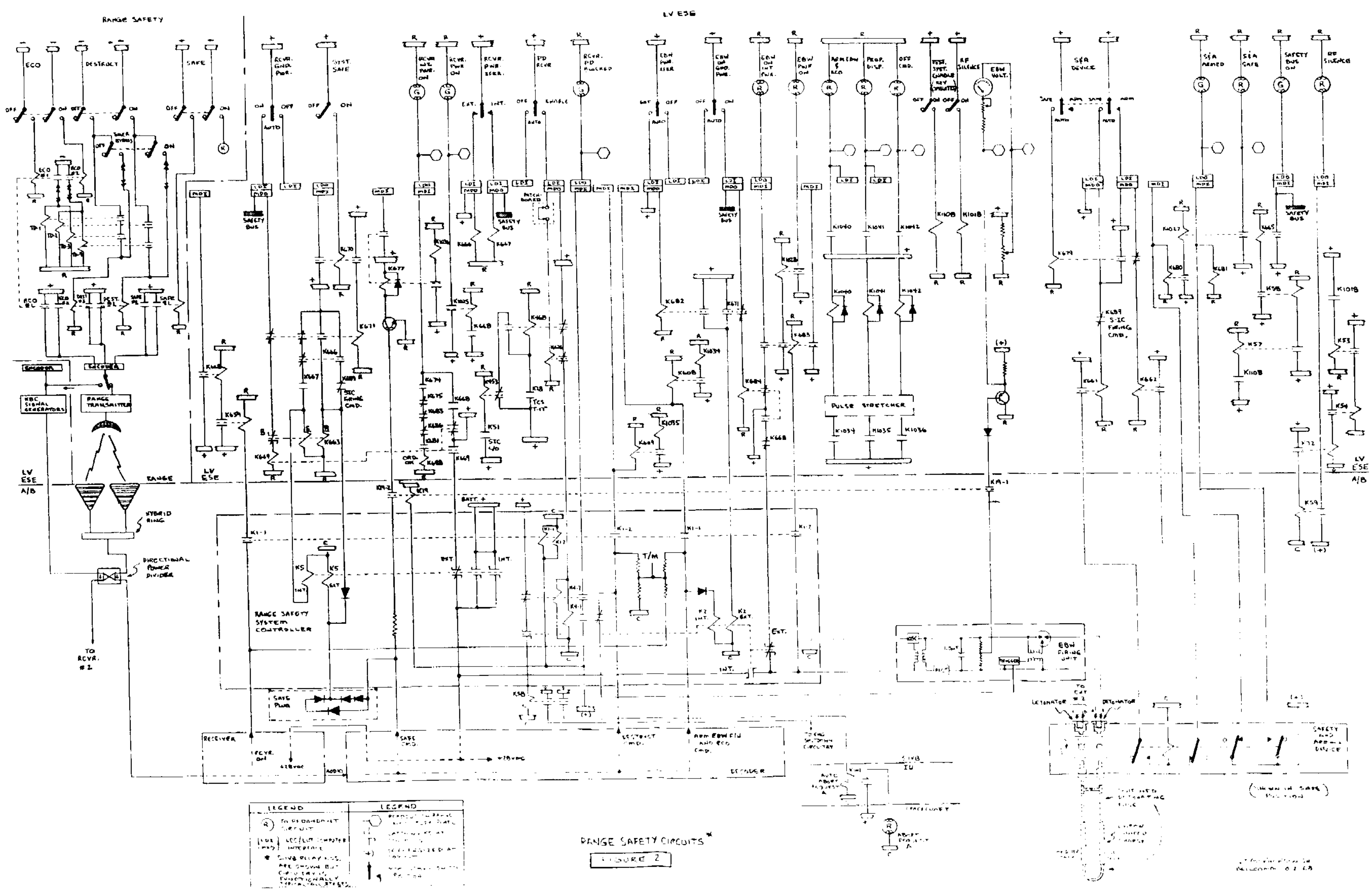
SATURN V PROPELLANT DISPERSION INSTALLATION

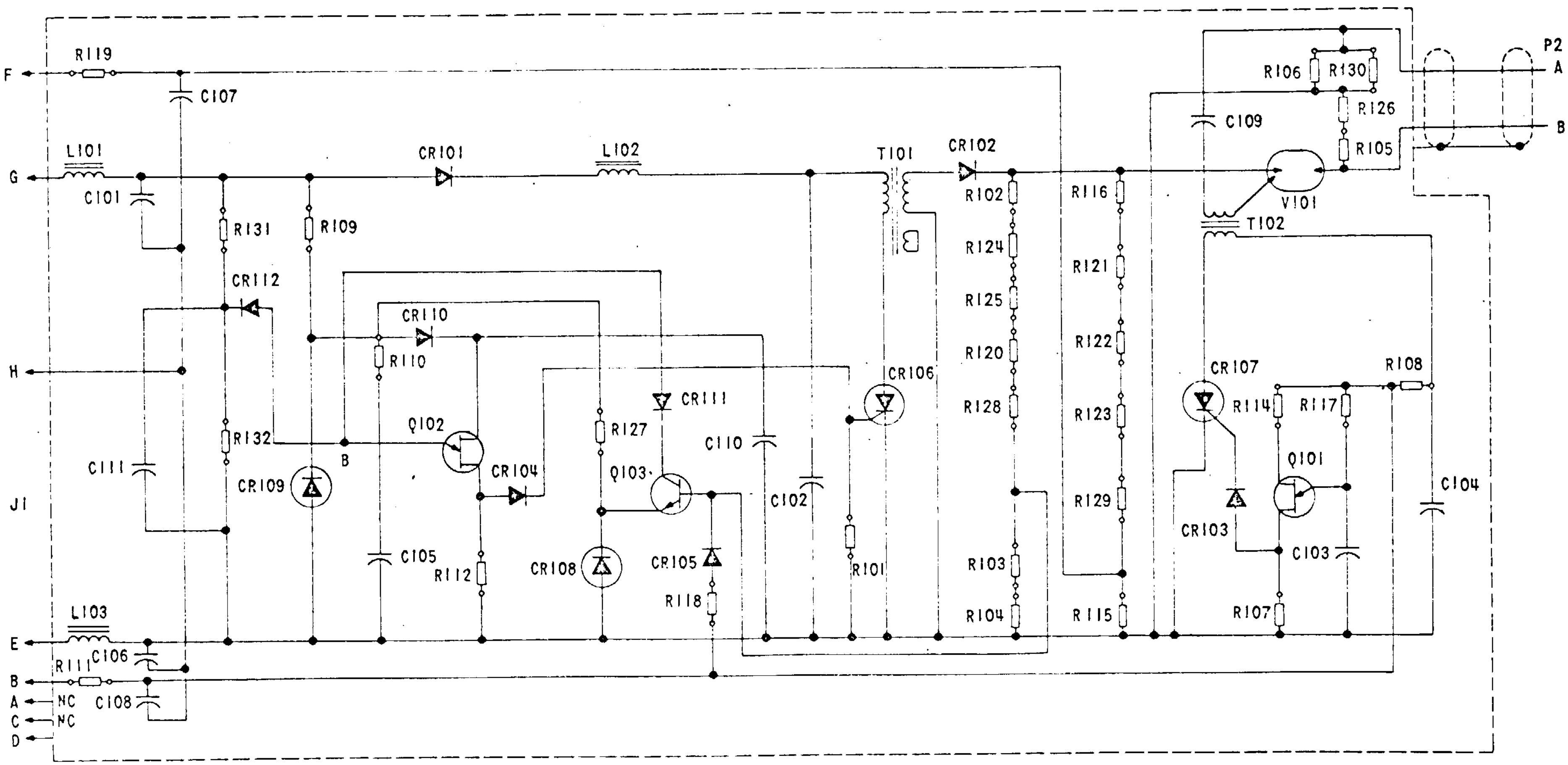


SATURN V PROPELLANT DISPERSION SYSTEM

FIGURE 1


RANGE SAFETY
ECO
DESTRUCT
SAFE
OFF
ON
TIMER BYPASS
ECO #1
ECO #2
TD-1
TD-2
TD-3
TD-4
DEST #2
DEST. #1
SAFE #2
SAFE #1
ENCODER
KBC SIGNAL GENERATORS
RANGE TRANSMITTER
LV ESE A/B
RANGE
HYBRID RING
DIRECTIONAL POWER DIVIDER
TO RCVR. #2
S&A DEVICE
SAFE
ARM
AUTO
S&A ARMED
S&A SAFE
SAFETY BUS ON
RF SILENCE
LDI
LDO
MDI
MDO
SAFETY BUS
K679
K1027
K665
K680
K681
K58
K1018
K689 S-IC FIRING CMD.
K57
K53
K1108
K54
K661
K662
K668
K659
K669
K72
K59
K1-1
RANGE SYSTEM CONT
EBW FIRING UNIT
TO CKT #2
DETONATOR
RECEIVER
RCVR. ON
SAFETY AND ARMING DEVICE
(SHOWN IN SAFE POSITION)
G.J. McPHERSON JR.
BELLCOMM 8-2-68


RANGE SAFETY
LV ESE
ECO
DESTRUCT
SAFE
RCVR. GND. PWR.
SYST. SAFE
RCVR. PWR. XFER.
PD RCVR
RCVR. PD PULSED
EBW PWR XFER
EBW ON GND. PWR.
EBW ON INT PWR.
EBW PWR ON
PROP. DISP.
OFF CMD.
RF SILENCE
EBW VOLT.
S&A DEVICE
S&A ARMED
S&A SAFE
SAFETY BUS ON
RANGE TRANSMITTER
HYBRID RING
DIRECTIONAL POWER DIVIDER
TO RCVR. #2
RANGE SAFETY SYSTEM CONTROLLER
SAFE PLUG
RECEIVER
DECODER
PULSE STRETCHER
EBW FIRING UNIT
SAFETY AND ARMING DEVICE
DETONATOR
RANGE SAFETY CIRCUITS*
FIGURE 2
LEGEND



J1 B TRIGGER INPUT
E 28 VDC RETURN
F OUTPUT CAPACITOR MONITOR
G ECO/ARM SIGNAL

EBW F/U SCHEMATIC DIAGRAM

FIGURE 3

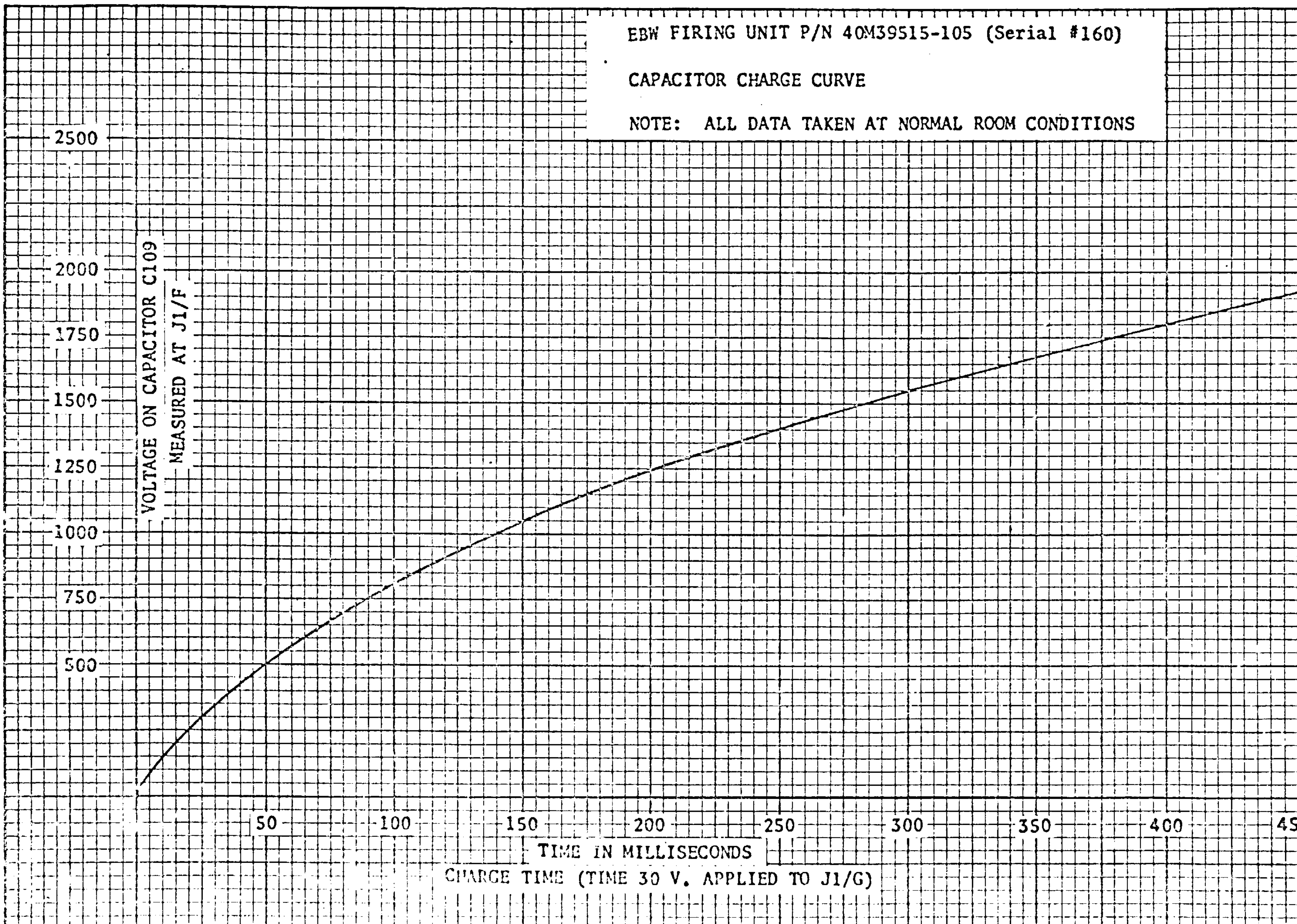

EBW FIRING UNIT P/N 40M39515-105 (Serial #160)
CAPACITOR CHARGE CURVE
NOTE: ALL DATA TAKEN AT NORMAL ROOM CONDITIONS
VOLTAGE ON CAPACITOR C109
MEASURED AT J1/F
2500
2000
1750
1500
1250
1000
750
500
50
100
150
200
250
300
350
400
450
TIME IN MILLISECONDS
CHARGE TIME (TIME 30 V. APPLIED TO J1/G)

FIGURE 4

ADDENDUM I

HARDWARE DESCRIPTION

PROPELLANT DISPERSION SYSTEM

Each stage of the Saturn V launch vehicle has a completely redundant (except for passive devices) Propellant Dispersion System (PDS). The S-IC, S-II, and S-IVB PDS's are functionally identical and together form the LV Flight Termination System (FTS). A simplified block diagram of the FTS and a 3-dimensional sketch of the PDS ordnance installations is presented in Figure 1. A typical PDS shall be discussed.

The purpose of the PDS is to allow ground-initiated RF commands from the Range Safety Officer (RSO) to terminate booster thrust and/or disperse the remaining propellants should the SV trajectory stray outside its Range Safety limits. The termination of booster thrust provides the capability to limit booster impact to within an acceptable footprint. The dispersion of the remaining propellants at altitude allows for dissipation of the majority of the LV's destructive potential prior to land impact. The PDS also provides the capability to "safe" the S-II and S-IVB systems once they are no longer needed.

The PDS (see Figures 1 and 2) consists of two UHF antennas (four on the S-II stage) tied together by a common hybrid ring. The hybrid ring sends commands received by both antennas to a directional power-divider which in turn sends all received commands to both receivers. Directional couplers (see Figure 2) are provided which act as RF check valves preventing signals (received closed-loop) from reaching the antenna where it would radiate energy. Each receiver inputs to its own decoder which, if a properly coded message is recognized, will issue a discrete to the RSS Controller. The controller in turn will issue the initiating signals to the engine shutdown circuitry, the Exploding Bridgewire (EBW) Firing Unit (F/U), or the receiver power control relay (within the RSS controller) in the case of a Safe command. The F/U upon receipt of the proper signals will send a high-voltage, high-energy signal to the EBW detonators to initiate the detonation train.

With the S&A devices in the armed position, the detonation train will propagate from the detonator, through the S&A device to the Confined Detonating Fuse (CDF), and through the CDF to the Linear Shaped Charge (LSC) which cuts the respective LV propellant tanks. An ordnance "T" is provided between the two CDF trains to provide additional redundancy.

ELECTRICAL SUPPORT EQUIPMENT (ESE)

Each stage has its own ESE for checking out (hard-line), controlling, and monitoring its respective PDS system. Each set of ESE provides the following basic capabilities (see Figure 2):

a. arm and safe the S&A device

b. monitor the S&A device position

c. power-up and power-down the decoder/receiver on either ground or A/B power

d. monitor the decoder and receiver power status

e. power-up and power-down the EBW F/U on ground power

f. monitor EBW F/U status including the output capacitator charge voltage

g. monitor decoder discrete output signals

In addition, common ESE can control and monitor the total LV FTS as follows (see Figure 2):

a. Range Safety Supervisors Console - monitors RF silence and pertinent status from each stage's PDS.

b. Vehicle Network Panel - disable individual stage ESE control of decoder/receiver and EBW/FU power-up by removing power from the respective Safety Bus.

c. Test Supervisors Panel - initiate RF silence.

COMMAND RECEIVERS

The RSS command receivers receive a modulated composite RF signal via the antenna/hybrid ring/power-divider network. The command receiver demodulates the RF carrier and furnishes a composite audio baseband signal to the decoder.

DECODER

The RSS decoder receives the receiver audio output and detects the individual tones present. Only the proper sequence and combinations of tones will satisfy the decoder logic and cause the function relays to output the desired 28 vdc pulse to the RSS controller. Output pulse duration to the controller is approximately 20 milliseconds in duration. Neither the receiver nor the decoder locks-up any commands but will follow each input command from the command transmitter. The decoder logic clears itself every 180 milliseconds and is then ready to process the next message.

Automatic reset of the address registers within the decoder with power removal assures that a complete message (address and function words) is required in order to obtain an output once power is reapplied.

CONTROLLER

The RSS controller is used to apply power to, control, and monitor a command receiver/decoder combination and its associated EBW F/U. It also receives the 28 vdc pulse output commands* from the decoder and in turn issues the proper command to the engine shutdown relay, the EBW F/U, or in the case of a Safe command will remove decoder/receiver power.

EXPLODING BRIDGEWIRE FIRING UNIT (EBW F/U)

The EBW F/U consists of solid state circuitry which will, when the 28 vdc (continuous) Arm command is received from the RSS controller, amplify the 28 vdc to approximately 2300 vdc which is applied across and stored by an output storage capitor. The stored energy is released to the EBW detonator in the S&A device when the 28 vdc trigger pulses received from the decoder via the RSS controller cause a gap tube in the output circuit to break down.

EBW DETONATOR

The EBW detonators which screw into the S&A device housing, consist of a combination PETN** charge containing a low-resistance bridgewire. The discharge of the F/U

---

*There are five decoder output commands possible but only three--Arm/Fuel Cutoff, Destruct, and Safe--are implemented.

**Described in Addendum III.

storage capacitor high voltage, high energy output through the bridgewire causes the bridgewire to explode with a large, rapid release of energy. This energy provides the proper combination of heat and shock necessary to detonate the PETN. Detonator response time is 5 microseconds or less. The bridgewire circuit within the EBW detonator contains an air gap to prevent stray voltages from dudding* the unit. The detonator is designed to prevent "blow-back" of any explosive products into the electrical connector.

SAFETY & ARMING (S&A) DEVICE

The S&A device provides a means for remotely arming and safing the PDS ordnance train. As can be seen in Figure 1, a single S&A device provides a redundant explosive train capability. This is accomplished by means of two, isolated explosive trains (PETN) within a rotatable-unidirectional shaft. When the device is armed, the explosive trains are aligned with the EBW detonators on the input and the CDF's on the output. The shaft position is controlled by a 28 vdc solenoid (rotates 90° each time it is energized) operating through a ratchet clutch. Cam-operated microswitches interrupt or arm the respective signals to the control solenoid when the shaft reaches the desired position. A second set of cam-operated microswitches provides remote monitoring capability to the LCC without jeopardizing the control circuitry. Note: The S&A devices require a verification test in the laboratory within seven days of launch.

CONFINED DETONATING FUSE (CDF)

The CDF assemblies consist of a flexible fuse assembly with machined end fittings. The fuse is formed by a PETN filled lead core which is enclosed in a polyethylene plastic tube. The plastic tube is, in turn, wrapped with 10 continuous layers of fiberglass. The machined end fittings contain small booster charges which will detonate the fuse. The booster charge is designed to detonate when initiated by the EBW detonator via the S&A explosive train. The fuse assembly will propagate the explosion at a rate of 23,000 ft/sec. while completely containing the explosive process. The propagated explosion is used to detonate the LSC.

*Discussed in Addendum III.

LINEAR SHAPED CHARGE (LSC)

The LSC assemblies consist of a reasonably flexible, enclosed, explosive train with machined end fittings. The explosive train is composed of vee shaped PETN (S-IC) or RDX* (S-II and S-IVB) cores surrounded by a plastic jacket (S-IC) or aluminum sheath (S-II and S-IVB). The LSC's are mounted on the exterior of the propellant tanks (sides or bottoms) and are designed to cut slots in the respective tanks causing the remaining propellants to disperse.

RANGE SAFETY OFFICER (RSO) CONSOLE AND TRANSMITTER SITES

The RSO console which is located in the Range Control Center at Cape Kennedy originates all commands to the FTS, both during open-loop prelaunch checkout and during booster flight. Closed-loop checkout can be accomplished from either the RSO console or the KSC RF facility. For the Apollo Program, the console is configured to provide three discrete signals: Arm/Fuel Cutoff, Destruct, and Safe. Each of the three commands has a corresponding hooded toggle-switch.

The discrete signals commanded by the RSO are sent to all three range transmitter sites (Cape Kennedy, Grand Bahama, and Grand Turk). Only one transmitter will be broadcasting at any one time. Transmitter handovers to GBI and GTK will occur at approximately plus 2 minutes and plus 5 1/2 minutes, respectively. The discrete signals received at the transmitter sites (via hardline) are furnished to the command encoders which will in turn furnish an audio output to modulate the transmitter carrier (see Figure 2).

The encoder/transmitter is capable of issuing a complete message every 200 milliseconds. Message width (includes address word and function word) is $\approx$115 milliseconds in duration.

PULSE SENSOR UNIT

The pulse sensor unit connects directly to the output cable of the EBW F/U. The purpose of the pulse sensor unit is to allow an end-to-end functional check of the PDS with the proper resistive load to verify that the energy delivered by the F/U meets the EBW detonator "ALL FIRE" minimum values.

The proper energy delivered to the pulse sensor unit causes its solid state circuitry to "trip" and lock-up. The pulse sensor unit provides remote indications through the Overall Test Set (OATS) and is remotely reset from same.

---

*Described in Addendum III.

ADDENDUM II

CIRCUIT DESCRIPTION

The circuits reflected in Figure 2 were taken from the Apollo/Saturn V Safety Circuits, AS-503--The Boeing Company. The designator numbers correspond to the S-IVB configuration but the circuits are functionally similar to those of the S-IC and S-II stages.

SAFETY AND ARMING (S&A) DEVICE (CONTROL)

S&A device Safe and Arm signals originate at the respective Propellant Dispersion (PD) Console for each stage. The S&A DEVICE control switch is a three-position toggle switch--SAFE, AUTO, and ARM. The ARM position, however, is momentary and spring-loaded to return to the AUTO position.

With the S&A device in the Safe position, an Arm signal would be initiated by depressing the momentary switch to the ARM position and energizing K662. Upon K662 contacts closing, the Arm signal is sent through closed "Safed" micro-switch contacts in the S&A device to the control solenoid. The control solenoid drives the S&A rotor 90° through a ratchet clutch device at which time the energizing voltage is removed by the now-opened microswitch contacts. The safe circuit has concurrently been "Armed" by the closing of the "Armed" microswitch contacts. A separate set of "Armed" and "Safed" microswitch contacts provide remote monitoring capability to the ESE.

The "safing" of the S&A device is identical to the arm procedure except the control switch can be retained in the SAFE position maintaining voltage on the coils of K679 and K661 and in turn on the "Armed" microswitch contacts. This provides two safeguards against inadvertent arming. First, a set of K679 contacts are in the arm circuit downstream of the computer interface which would interrupt any inadvertent computer outputs. Secondly, with power maintained on the "Armed" microswitch contact, should the S&A device in any way rotate to the arm position, it would immediately be commanded back to the safe position. A set of K689 (S-IC Firing Command) contacts is provided in the safe circuit downstream of the computer interface to prohibit intentional or accidental "safing" of the S&A's once launch is imminent. Should an engine cutoff occur, the K689 contacts would close "arming" the safe circuit for use. It should also be noted that the safe circuit is completely redundant from the control switch to the output of the LUT computer interface.

S&A device status is monitored on the individual stage PD Consoles as well as on the Range Safety Supervisor Panel.

DESTRUCT SYSTEM ENABLE

The DESTRUCT SYSTEM ENABLE switch is a two-position key operated switch located on the Vehicle Network Panel. Placing the control switch in the ON position energizes relay K1108. Through a series of relay slave circuits (K57, K58, K665), power is applied to each stage's Safety Bus. This provides each with the capability to apply ground power to the decoder/receiver and EBW F/U; also, to transfer the decoder/receiver to the A/B power source.

Placing the control switch in the OFF position removes power from the Safety Bus, hence, disabling all of the aforementioned circuits. The circuits are disabled within the LUT computer interface which again provides assurance against a computer malfunction issuing an inadvertent signal.

RF SILENCE

The RF Silence switch is a two-position toggle switch located on the Test Supervisor Panel. Placing the switch in the ON Position energizes K1018 which in turn through a series of relay slave circuits (K53, K54, K72, and K59) illuminates an indicator on each of the stage PD Consoles, the Test Supervisor's Panel, and the Range Safety Supervisor's Panel informing them that RF silence is in effect. Through other circuitry (not shown), the RF Silence signal will automatically remove power from LV RF sources.

SYSTEM SAFE

The system Safe capability is provided on each PD Console to allow their inhibiting application of either ground or A/B power to the decoder/receiver and EBW F/U. The System Safe circuit is controlled by a two-position toggle switch. Placing the switch to the ON Position energizes K670 which in turn energizes K671. K671 contacts interrupt the decoder/receiver ground power circuit and the decoder/receiver power transfer to internal circuit; they also close the circuit to and energize K663 (Reset) and K5 (External) which would also remove all A/B power from the decoder/receiver and EBW F/U. Additionally, K671 contacts interrupt the EBW on ground power circuit and energize K2 (External) which would remove all A/B power from the EBW F/U.

When the SYSTEM SAFE switch is placed in the OFF position, ESE control of power application is re-enabled.

RSS CONTROLLER ISOLATION CIRCUITS

Relays K1-1 and K1-2 (within the RSS Controller) and relay K19 (external to the RSS Controller) are energized continuously provided the stage indicator bus remains powered up and the umbilical carrier connectors are mated. During the terminal count, the indicator bus is de-energized by the Commit signal from the S-IC ESE. This will de-energize the isolation relays which in turn will interrupt those circuits where it is undesirable to disconnect the umbilical carrier connectors with voltage applied.

DECODER/RECEIVER POWER-UP/POWER TRANSFER/POWER-DOWN

To apply power to the decoder/receiver,* the stage Safety Bus must be powered-up and the stage SYSTEM SAFE switch must be in the OFF position.** With these conditions existing, decoder/receiver ground power can be controlled by the RCVR GND PWR three-position toggle switch. Placing the switch to the ON position energizes K669 through the closed K671 and K663 contacts. K669 contacts in turn apply ground power to the equipment through the closed K5 contacts.

Transfer of the decoder/receiver to A/B power is controlled by the RCVR PWR XFER three-position toggle switch. Both the INT (internal) and the EXT (external) positions are spring-loaded to return to the center position. Momentarily placing the switch to the INT position will energize K667 which will in turn energize K663 (Set) and K5 (Internal). Relay K663 interrupts the ground power control signal while relay K5 contacts will interrupt the ground power circuit and apply battery bus voltage directly to the decoder/receiver.

---

*The receiver power is applied through the decoder.

**If the S&A device ordnance is connected, the Range requires that either the Range or KSC carrier be brought up prior to powering-up the decoder/receivers. This assures immediate capture of the receivers by the correct carrier which protects the receiver input from other than intentional commands.

Placing the control switch to the EXT position will energize K666. K666, through the closed contacts of K689, will energize K663 (Reset) and K5 (External). These will in turn remove A/B power and apply ground power. Ground power is removed by placing the RCVR GND PWR switch to the OFF or AUTO positions which de-energizes K669.

A set of normally closed K689 (S-IC Firing Command) contacts are provided in the decoder/receiver external power control circuitry to prevent transfer of the equipment back to ground power once launch is imminent. Decoder/receiver power-on is monitored at the ESE via K659 which in turn energizes K668.

EBW F/U POWER-UP/POWER TRANSFER/POWER-DOWN

To apply power to the EBW F/U, the stage Safety Bus must be powered-up and the stage SYSTEM SAFE switch must be in the OFF position. EBW F/U ground power application is controlled by the EBW ON GND PWR three-position toggle switch. Placing the switch in the ON position will energize K684 through the closed contacts of K671 which in turn applies ground power through the normally closed contacts of K668 and K2. It should be noted that the K668 contacts will be open whenever the decoder/receiver is powered-up. This prevents inadvertent power-up of the EBW F/U any time the decoder/receiver are powered-up.

The ESE does not have the capability to transfer the EBW F/U to A/B power. Power transfer can only be initiated through the command receiver input. A properly received/decoded message will cause the decoder to output the ECO discrete (ARM EBW F/U and ECO) which will energize K2 (Internal) applying either ground or A/B power to the EBW F/U dependent upon the position of the K5 contacts.

Application of either ground or A/B power to the F/U input (J1-G) (see Figures 3 and 4 - F/U Schematic and Charge Curve) will cause C105 to charge and turn on Q102. Q102 in turn will allow CR106 to conduct through the primary of transformer 101. This induces a high voltage pulse on the secondary of T101 which is stored by C109.

The initial action which was started by the charge on C105 will be likewise ended as C105 discharges through Q102 and R112. When C105 has discharged sufficiently to allow Q102 to turn off, the circuit in effect has been reset and starts anew with C105 again charging and enabling Q102. This creates the oscillatory effect which continues until Q103 senses C109 has been fully charged. Q103 will then regulate the frequency of the charging oscillations to maintain full charge on C109 which is constantly losing some of its charge through the redundant bleeder networks. The charge on C109 cannot break down the gap tube itself without a discharge pulse from the trigger circuit.*

Removal of power from the circuit input will allow C109 to discharge completely through the bleed circuits. The specification value for discharge of C109 is from 2300 vdc down to 300 vdc in 15 seconds or less. Also, each of the redundant bleed circuits are required to be capable of individually discharging C109 to 300 vdc within 90 seconds.

The power applied to the F/U is monitored via K683 and K1028. The discrete (ARM EBW F/U and ECO) out of the decoder is monitored by telemetry (S-IC and S-II only) and stage ESE via K608, K1034, and K1040 (pulse stretcher network). The actual charge voltage across output capacitor C109 is displayed on an ESE voltmeter (EBW VOLT) via a solid state sensing circuit.

Input power can be removed from the F/U by placing the EBW PWR XFER switch to the EXT position which energizes K682. K682 in turn energizes K2 (External) interrupting power supplied through either set of K5 contacts. Even though the EBW ON GND PWR switch may have been left in the ON position, ground power will not be reapplied to the F/U until the decoder/receiver is powered-down and K668 de-energizes.

EBW F/U TRIGGER CIRCUIT (DESTRUCT COMMAND)

The EBW F/U trigger circuit is designed to receive a 28 vdc signal directly from the decoder (through contacts of K4-1)* and within 4 milliseconds provide a high voltage pulse to the third electrode of the gap tube. The ensuing arc between the input electrode and the trigger electrode ionizes the tube gas which provides a conductive path between the input and output electrodes. This allows the energy stored in the output capacitor C109 to discharge to the EBW detonator.

---

*Will be discussed in the subsequent section.

Since neither the decoder nor the RSS controller contains any lock-up circuitry for the Destruct signal, the signal seen by the EBW F/U trigger circuit will be a 28 vdc 20 ms pulse at 200 ms intervals. The trigger circuit will have adequate time to "trigger" the gap tube at least four times during each Destruct pulse received.

The trigger circuit also provides a feedback signal to the main charge circuit through CR 105 (see Figure 3) which turns on Q103 and disables the charge circuit. Removing the charge circuit load from the stage battery prevents undue battery drain during discharge of C109 through the gap tube to the EBW detonator.

During the 180 ms "dead time" between Destruct pulses out of the decoder, the charge circuit would be re-enabled. The test data of Table 2 indicates that the output capicitor C109 would again reach a voltage level adequate to allow another breakdown of the gap tube by a trigger pulse some 400 ms later. All gap tube breakdowns subsequent to the initial C109 discharge will provide less voltage than the specified EBW detonator "ALL FIRE" value. This is academic, for actual usage in flight, since the first gap tube breakdown would provide the propellant dispersion event.

The Destruct signal cannot be initiated from the stage ESE but must be originated at either the RSO console or the KSC RF facility. Open or closed-loop signals originated at either location must be processed by the receiver and decoder to reach the F/U. The Destruct signal out of the decoder is monitored by telemetry (S-IC and S-II only) and stage ESE via K609, K1035, and K1041 (pulse stretcher network).

PROPELLANT DISPERSION (PD) BLOCK CIRCUIT

The purpose of the PD Block circuit is to provide the means for interrupting the Destruct and ECO signals within the RSS controller until late in the terminal countdown. This prevents both test and/or inadvertent Destruct signals from reaching the F/U trigger circuit and likewise an ECO signal from reaching the stage engine shutdown circuitry. The latter also prevents illumination of the SC Abort Advise indicators.

The PD Block function is furnished via K4-1 and K4-2 which are energized continuously through normally closed contacts of K468 and K676 in the ESE until the proper time in the terminal countdown. During normal operation, K468 is energized at T-17 seconds by the Terminal Count Sequencer (TCS) which de-energizes relays K4-1 and K4-2. This arms the Destruct and ECO circuitry within the RSS controller. Since the T-17 second signal out of the TCS is only momentary, a lock-up circuit is provided for K468 through normally closed contacts of K453. K453 will interrupt the lock-up circuit in the event of a "cutoff."

The other normally closed contact (K676) in the K4-1 and K4-2 solenoid circuit provides an end-to-end checkout capability for the Destruct and ECO circuits. Relay K676 is controlled by the PD RCVR three-position toggle switch. When placed in the ENABLE position, a signal is sent to K676 through a special patch in a LUT equipment rack. Energizing K676 will de-energize K4-1 and K4-2 allowing the Destruct and ECO signals emitted from the decoder to reach the EBW F/U and engine shutdown circuitry.

The special patch in the LUT equipment rack provides a positive means for inhibiting the checkout capability. The patch is removed subsequent to the final PDS checkout with the pulse sensor units and prior to actual connection of the S&A device ordnance. The PD block circuit is monitored on the ESE via contacts of relays K4-1 and K4-2.

PDS SAFE

The capability to "safe" the PDS's during or subsequent to boost flight exists within the hardware of all three LV stages but is only planned to be implemented on the S-II and S-IVB stages of manned Apollo/Saturn V SV's. The capability is "armed" by the installation of a safing plug (see Figure 2) on a particular connector of the RSS controller unit.

The connector contains redundant circuitry which ties the Safe command out of the decoder to the EXT (External) solenoid of K5. Energizing K5 EXT removes the decoder/receiver from the A/B battery source and closes the path to the ground power circuit. Since no ground power source is available in flight and since the capability to energize K5 INT (Internal) in flight does not exist, the PDS is permanently safed.

It should also be noted that the stage ESE cannot initiate the SAFE command. All verification of the Safe circuitry is accomplished via RF open or closed-loop. The SAFE command out of the decoder is monitored by the ESE via K677, K1036, and K1042 (pulse stretcher network).

ORDNANCE OK CIRCUIT

The Ordnance OK circuits for the S-II and S-IVB are similar and will be discussed first. The Ordnance OK relay K688 (see Figure 2) is energized through a summation of K681, K686, K683, K675, K674, K668, and K669 contacts. The following conditions must exist in order for K688 to be energized:

1. command reveivers 1 and 2 must have power applied

2. the S&A device must be armed

3. EBW F/U's 1 and 2 must <u>not</u> be powered-up

4. command receivers 1 and 2 must <u>not</u> be commanded on ground power.

Providing the above conditions continue to be satisfied, a set of K688 contacts will remain closed in the S-IVB Stage Ready For Firing circuit (not shown). A set of the S-IVB Stage Ready For Firing relay contacts (K968) are in turn part of the Firing Preparation complete summation circuit which is a prerequisite for starting the TCS at T-3 minutes 7 seconds. The S-II stage has a similar function in the K968 circuit.

The S-IC PDS ordnance circuits are summed similar to the K688 circuit of the S-IVB stage but is utilized directly in the Firing Preparations Complete circuit. Hence, if any of the LV PDS circuits are not in the proper condition prior to TCS start, the TCS sequence will automatically be inhibited. The circuits are also verified later in the TCS sequence and will cause an automatic cutoff should their condition change.

RANGE SAFETY OFFICER (RSO) CIRCUITS

The RSO has the capability of sending three commands (<u>ECO</u>, <u>Destruct</u> and <u>Safe</u>) to the LV, either closed-loop or open-loop. The commands are initiated from hooded, two-position, double-pole toggle switches located on the RSO console in the Range Control Center. Each of the control circuits are redundant as indicated in Figure 2. The redundant aspects of the system will not be discussed herein.

As can be seen in Figure 2, any command sent into the encoder could be transmitted in either of two ways to the LV. During closed-loop checkout the encoder outputs are sent to the KSC RF station where they are used to modulate signal generators. The signal generator outputs are hardlined to the LV receivers via the power divider network. The signal at the receiver input looks identical to those transmitted open-loop.

During open-loop testing and for mission support, the hardline path is interrupted and all encoder outputs are sent to the command transmitter where they modulate the command carrier. The modulated signal is transmitted to the LV antennas via air-link and sent to both reveivers via the hybrid ring/power divider network.

All input commands to the Cape Kennedy encoder would also be transmitted via hardline to the GBI and GTK encoders during mission support and would modulate the carrier of whichever transmitter was broadcasting.

The ECO command is issued by placing the ECO toggle switch to the ON position energizing the ECO relay. ECO relay contact closure initiates two separate actions. First, a signal is sent to the encoder which causes the ECO command to be transmitted to the LV.. Secondly, four Time-Delay (TD) relays are energized which will, upon timing out, arm the Destruct circuit.

The Destruct command is issued by placing the DEST toggle switch to the ON position which will energize the Destruct relay providing the TD relays have timed-out. The closing of the Destruct relay contacts will send a signal to the encoder and cause the Destruct command to be transmitted to the LV. Since the ECO signal is necessarily present (or else the TD relays would reset) at the input of the encoder when the Destruct signal is sent, a priority interrupt circuit is provided which allows the Destruct command to be transmitted without removing the ECO command from the encoder input.

Since it is not feasible to retain the ECO toggle switch in the ON position (arms the EBW F/U) during the final DRSCR checks with the S&A ordnance connected, a timer BYPASS switch has been provided to allow arming the Destruct circuit without energizing the ECO relay. It is not intended for the BYPASS switch to be used during mission support unless the Destruct circuit fails to function after the time-delay has expired.

The Safe command is issued by placing the SAFE toggle switch to the ON position which energizes the Safe relay. The closing of the Safe relay contacts will send a signal to the encoder which will cause the Safe command to be transmitted to the LV.

In all cases (ECO, Destruct, and Safe), the commands once initiated will continue to be transmitted to the LV until either the respective toggle switch is placed in the OFF position or until a higher priority command is initiated.

BELLCOMM, INC.

ADDENDUM III

ORDNANCE CHARACTERISTICS

1.0 INTRODUCTION

Two explosives are used in the Saturn V PDS, penta-erthyrite tetranitrate (PETN) and cyclotrimethylene tri-nitramine (RDX). The S-IVB Ordnance Train (Table 1) is reasonably similar to those of the S-IC and S-II and is included as a representative usage of the two explosives. The only significant differences are in the amounts of explosive and the use of PETN rather than RDX in the S-IC LSC.

The following discussions are in three parts: EBW detonator, PETN, and RDX. The EBW detonator* which contains two classes of PETN (see Table 1), has been designed to display specific electrical characteristics which are unrelated to the inherent properties of the PETN within. The first section will be concerned with the detonator electrical characteristics. The subsequent two sections will address some of the properties of the two explosives.

2.0 EBW DETONATOR

The EBW Detonators have been designed to prevent accidental detonation from any stray voltage that could possibly be present on the Saturn V launch vehicle. In addition, it has built-in protection against static discharge, radiated RF energy, and dudding.**

Protection against dudding is provided by an air gap within the detonator electrical circuit. The air gap is created by a small square of mica material inserted between two halves of one of the electrical pins in the connector. A voltage differential of greater than 600 volts is required to break down the gap. This also eliminates low-order static discharges.

---

*Future units may contain RDX instead of PETN. The bridgewire resistance will be slightly lower and the energy released by both the bridgewire exploding and the RDX detonating will be slightly higher than the PETN units. This will not influence any of the discussions in this study.

**Ordnance which has been exposed to levels of voltage and/or RF energy too low to cause detonation but adequate (in intensity and/or time) to sufficiently decompose it chemically and prevent future detonation from its normal source.

Protection against radiated RF energy and the higher-order static discharges is an intrinsic part of the exploding bridgewire. The bridgewire requires a certain minimum level of energy in order to generate the correct combination of shock and heat required to detonate the PETN. Anything other than the correct combination of shock and heat could result in dudding.

The following data is the specification* NO FIRE values. That is, the EBW detonator can be exposed to the indicated levels of energy and will not detonate.

STRAY VOLTAGE**

36 vdc	via 0.1 ohm impedence for 15 minutes
115 vac (60 cycles)	via 0.2 ohm impedence for 15 minutes
115 vac (400 cycles)	via 1.0 ohm impedence for 15 minutes
250 vac (60 cycles)	via 0.2 ohm impedence for 15 minutes
250 vac (400 cycles)	via 1.0 ohm impedence for 15 minutes

STATIC DISCHARGE**

9000 vdc via 500×10^{-12} F capacitance

RADIATED

100×10^{-3} watts/CM^2 (2-30,000 mc) continuous

UNDERCHARGED FIRING UNIT**

500 vdc via 1.0×10^{-6} F capacitance

A more practical statement of the NO FIRE values for the EBW detonator as expressed in Reference 16 are as follows.

1 watt for 5 minutes
1 ampere for 5 minutes

The specification ALL FIRE (will always detonate) minimum value is: 1800 vdc via 0.75×10^{-6} F capacitance. Nominal detonation signals out of the EBW F/U are: 2300 vdc via 1.0×10^{-6} F capacitance.

Another design feature (proven in qualification tests) of the EBW detonator is its ability to completely confine the detonation process. Once the EBW detonators have been installed in the S&A device housing, any detonation of

---

*See reference 14.

**Either pin-to-pin or pin-to-case.

either or both EBW detonators (with the S&A device in its Safe position) will be completely confined and will present no hazard to equipment or personnel. The S&A device housing contains vent ports to allow dispelling of the explosive by-products. A small plastic protective cap (covers the S&A rotor manual control screw) will blow off as a result of the detonation but does not present any hazard to informed personnel or equipment.

An indicator of the relative insensitivity of the EBW detonator to either shock or heat is realized from two of its specification* requirements. The detonator can be dropped 40 feet onto a steel plate and can withstand temperatures up to 300°F for 20 minutes, both without detonation. Additionally any unit exposed to those environments would be considered safe to handle subsequent to their exposure.

3.0 PETN

Temperature Sensitivity

100°C (212°F) - quite stable for 100 hours

120°C (248°F) - begins to decompose rapidly (not unduly toxic)

141°C (284°F) - melts

160°C (320°F) - @2mm Hg } boils

180°C (356°F) - @50 mm Hg } boils

210°C (410°F) - continues rapid decomposition, in some cases explosively

1974 cal/gm @constant pressure - heat of combustion (oxidation)

225°C (440°F) - explosive temperature

Impact Sensitivity**

2 Kg weight from 6 inches (Picatinny Arsenal method)

2 Kg weight from 17 cm (Bureau of Mines method)

Note: The EBW detonator by specification can be dropped up to 40 ft onto a steel plate without being detonated.

Spark Sensitivity

Relatively insensitive (considered non-hazardous)

---

*See Reference 14.

**At least one explosion out of ten trials.

4.0 RDX

Temperature Sensitivity

≈100°C (212°F) - stable as TNT

≈150°C (302°F) - very stable for 40 hours

≈204°C (400°F) - melts (not markedly toxic)

≈2307 cal/gm @constant pressure - heat of combustion (oxidation)

≈260°C (500°F) - explosive temperature

Impact Sensitivity*

2 Kg weight from 8 inches @25°C (78°F)
2 Kg weight from 5 inches @105°C (224°F) } (Picatinny Arsenal method)

2 Kg weight from 33 cm (Bureau of Mines method)

Spark Sensitivity

Less than PETN

5.0 COMMENTS

The prior data on PETN and RDX has been included only as an indicator of how hazardous or non-hazardous (depending on the point of view) they are or can be depending upon the use or lack of necessary precautions when working near them. To the best of the author's knowledge, the type of testing which would output practical data, applicable to the Saturn V LV, has not been accomplished.

It should be noted, however, that Reference 16 does provide a more practical measure of impact sensitivity for the CDF and LSC assemblies as installed on the Saturn V launch vehicle. Neither will detonate when subjected to impact from a 10-pound, 1-inch diameter, steel weight dropped from a height of 16 feet.

Since several other factors would also influence the level of hazard associated with the PDS ordnance, they are listed here for consideration:

---

*At least one explosion out of ten trials.

1. Although both PETN and RDX would appear to be somewhat sensitive to fire, the temperatures indicated were determined using small samples of unprotected explosive material applied directly to a heat source. Since both the PETN and RDX are protected or encased to a significant degree (see Addendum II) and a fairly intense, sustained fire would be required to supply the necessary heat to the ordnance devices to cause detonation, it can be concluded that chances of detonation from a fire (other than one that is already catastrophic in nature) is very unlikely.

2. At the time personnel are connecting or disconnecting the S&A device ordnance, S-IC RP-1, S-IVB APS hypergolics, and SC hypergolics are the only flammable liquids aboard in sufficient quantity to be considered a sustained-fire hazard. Although all of these burn at temperatures 3 to 4 times (hydrazine 1300°F, RP-1 1800°F) that of the indicated explosive temperatures of PETN and RDX, it would take sufficient, sustained leakage in very close proximity to the ordnance as well as an ignition source before any immediate hazard of ordnance explosion would present itself. In this case, the ordnance crews would probably be in as much immediate danger from the fire as they would be the ordnance.

3. The reasonable inaccessibility of the CDF and particularly the LSC negate any likely hazard from impact or sparks.

4. The entire PDS system while being of hazardous nature has been designed to provide the safest possible components* and circuitry practical without undue compromise to its purpose. The system being flown on all Saturn V LV's is essentially identical to those flown on the latter Saturn I's and all Saturn IB's.

---

*See Reference 17 for PDS component and system reliability values.

ADDENDUM IV

DESCRIPTION OF OPERATIONS

S&A DEVICE CONNECTION/DISCONNECTION

As proposed originally by the Saturn V Countdown Working Group (CDWG), the S&A device connection operations would be performed with the MSS at the launch pad and a controlled number of personnel allowed access to continue with the launch preparations of the SV, LUT, and MSS. KSC Safety has since approved a plan to allow such an operation and requiring clearance of all personnel except the ordnance crews from within the SV below the CSM. Since the detonation of an EBW detonator into a "safed" S&A device is not nominally hazardous to personnel in the adjacent area, it must be assumed that the clearance requirements are to prevent interference with the ordnance crew operations.

Prior to commencing the S&A ordnance operation, the final (end-to-end) DRSCR open-loop and semi-final closed-loop checks are made with the EBW pulse sensor units connected. The open-loop command verifies the RF link from both Range command transmitters at the Cape to all LV command receivers. The receiver audio outputs are verified with a test command (test code plug installed) which is rejected by the decoder logic, hence, no signals out of the decoder.

During the closed-loop checks (flight code plug installed), the S&A devices are cycled, ECO and Destruct are verified with PD block removed (pulse sensors trip), and the stage engine systems verify receipt of the ECO signal. The PD block is then energized and both ECO and Destruct are verified not received out of the RSS controller. The Safe command is also verified which transfers the S-II and S-IVB decoder/receivers to external (no ground power applied) and the S-IC decoder/receivers are verified not affected.

Upon completion of the end-to-end DRSCR checks, the PD enable jumpers (see Figure 2) are removed (remain out for launch) which disables the ESE manual capability of removing the PD block function. Both the Destruct signal to the EBW F/U and the ECO signal to the engine circuitry are now continuously interrupted until the TCS T-17 second function. The pulse sensor units are also removed at this time and the LV is now ready for the S&A ordnance operations.

The first step (after implementing RF silence and controlled switching per KSC TI-2-13) in the operation is the stray voltage test of each output connector of the EBW F/U. The stray voltage test* actually consists of AC and DC voltage checks as well as resistance checks. During the stray voltage test, ground power is present on the main A/B buses and remains on during actual ordnance operations. Completion of the stray voltage tests is followed immediately by the ordnance connections.

One mechanical and several electrical safeguards will be effected during the actual electrical connection of the EBW detonator and the mechanical connection of the CDF. (See Addendums I and II for detailed descriptions of the hardware and circuitry):

1. RF silence and controlled switching will remain in effect per KSC Technical Instruction 2-13.

2. The S&A device will be verified in the <u>Safe</u> position.

3. The <u>Destruct System Enable</u> key switch will be in the <u>OFF</u> position and the key physically removed.

4. The <u>System Safe</u> switch will be in the ON position.

5. The PD Block circuit is energized and the ESE capability to de-energize it has been inhibited by the jumper removal.

6. The ETR command transmitter carrier is down.

One additional consideration which enhances overall system safety is the characteristics of the ordnance devices themselves described in Addendum III.

The actual connection operation consists of first the electrical connection of the two EBW F/U output connectors to the EBW detonators and then the mechanical mating of the two CDF connectors to the output side of the S&A device.

---

*Table 2 contains the allowable specification values for the voltage checks and the resistance checks. The table also includes some test data regarding the ability to detect a failure in the trigger circuit via the voltage check or resistance check. Effect of trigger circuit failure on the F/U output is also addressed.

The disconnection process is essentially the reverse operation with the same safeguards.

To summarize the safety of the foregoing operation, some assumptions and observations are presented:

1. It is assumed that it is extremely unlikely that the proper combination of heat and shock to initiate a sustained detonation would be generated by failures such as fires, vessel ruptures, mishandling of ordnance by personnel, etc. This probability is lessened even more by the fact that we are only considering a limited exposure time and location during S&A device connection/disconnection. It is also very difficult to imagine any <u>single</u> failure that would satisfy the minimum heat/shock detonation requirements.

2. It is also assumed that the concern over detonation of the ordnance train from <u>other</u> than a stray voltage during connection was not of any great concern based on the relative open access (all necessary personnel) prevailing once the S&A device ordnance is connected.

3. With the multitude of safeguards listed previously, a multiple failure (greater than a double failure) would be required to even "arm" the EBW F/U. On top of this, additional multiple failures would be required to activate the EBW F/U trigger circuit.

4. Were it even imaginable to conceive all of the failures of item 3 occurring relatively simultaneously, at just the time all possible preventative measures are effected, the S&A device is still mechanically in its <u>Safe</u> position and would limit the detonation to just the EBW detonator itself.

<u>FINAL LV/RANGE COMMAND CHECKS</u>

As being considered by the Saturn V CDWG, the final DRSCR checks would be accomplished identically, twice. The first check would be at approximately T-3 hours 25 minutes subsequent to LV cryogenic loading but just prior to the SC closeout crew proceeding to the pad. The second check would occur after the flight crew and SC were closed out, the AAA retracted to its 12° park position, and the SC pyro buses armed.

Both checks will be accomplished closed-loop from the RSO console via the KSC signal generators. The decoder, command receiver, and EBW F/U will all be powered from the internal (A/B) power sources during their respective participations.

ECO Signal Check

The ECO signal (Arm EBW F/U) will be initiated by the RSO and system response monitored via ESE and/or telemetry indicators. The safeguards (See Addendum II for detailed circuit descriptions) present during this test include the S&A device in the Safe position and the PD block circuit held energized.

The only possible single point failure which could lead to detonation of the EBW F/U detonator is accidental activation of the trigger circuit. This could occur by either a DC voltage fault downstream of the PD Block relay contacts or by an internal failure within the EBW F/U. The probability of either of these happening, at just this particular time and to circuitry/components which have been verified many times (including a functional check with the pulse sensor units at $\approx$ T-16 hours) is, again, extremely low.

A double failure mode is also available. Should the command receivers inadvertently issue a Destruct command at just the time the PD Block circuit failed, the EBW F/U trigger circuit would be activated.

Should either of the failure modes above occur, the explosive action would not proceed beyond the EBW detonator itself with the S&A device in the Safe position. At least one additional failure would be necessary to Arm the S&A device, again essentially simultaneously with the other failures to create a catastrophic situation.

Additionally, if any of the above failures occurred individually, a multitude of corrective actions such as command receiver power removal, DEST SYSTEM ENABLE switch to OFF, SYST. SAFE switch to ON, etc., are immediately available to eliminate the hazard.

Destruct Signal Check

Having just seen the ECO signal "arm" (charge) the EBW F/U and also having just seen the EBW F/U discharge (via the ESE voltmeter) when reset from the ESE, the Destruct command will be initiated by the RSO. To allow issuance of the Destruct command without the ECO signal present, the timer BYPASS switch must be closed.

The Destruct command out of the decoder will be blocked from the EBW F/U trigger circuit by the PD Block circuit which remains energized until T-17 seconds. The Destruct signal is verified via telemetry and/or ESE indicators.

A single failure within the PD Block circuitry could allow the Destruct command to reach the EBW F/U trigger circuit, but with the F/U uncharged, the gap tube would not break down. Should the multiple failures simultaneously occur which would provide adequate power to the EBW F/U charge circuit, the S&A device being in the Safe position would again limit the detonation to just the EBW detonator itself.

Another inherent characteristic of the EBW F/U design (discussed in more detail in Table 2 of Addendum II) is that, if the trigger circuit is activated prior to the charge circuit, the probability of successfully detonating the EBW detonator decreases and the chance of dudding increases.

As in the case of the ECO signal check, various corrective actions are immediately available to eliminate hazardous circuit conditions should a failure occur.

BELLCOMM, INC.

TABLE 1

S-IVB PROPELLANT DISPERSION SYSTEM ORDNANCE TRAIN

EXPLOSIVE	WEIGHT/DENSITY	APPLICATION
PETN	1.0 gr.* 1.4 gr.	EBW Detonator**
	2.5 gr.	S&A Explosive Train
	0.8 gr. 0.3 gr.	CDF Adapter End Fitting
	2.0 gr./ft.	CDF Train
	0.3 gr. 0.8 gr. 3.0 gr. 0.8 gr. 0.3 gr.	CDF TEE
	2.0 gr./ft.	CDF Train
  PETN	0.3 gr. 0.8 gr. 10.0 gr.	CDF to LSC Adapter on LSC
RDX	150 gr./ft	LSC Train
PETN PETN	6.0 gr. 6.0 gr.	LSC to LSC Connector (LH_2 tank)
RDX	150 gr./ft.	LSC Train
PETN	10 gr. 0.8 gr. 0.3 gr.	LSC to CDF Adapter on LSC
	2.0 gr./ft	CDF Train
  PETN	0.3 gr. 0.8 gr. 10 gr.	CDF to LSC Adapter on LSC
RDX	150 gr./ft.	LSC Train
PETN PETN	6.0 gr. 6.0 gr.	LSC to LSC Connector (LO_2 tank)
RDX	150 gr./ft.	LSC Train

*1 grain (gr.) = 0.648 grams.

**Future units may contain RDX instead of PETN.

TABLE 2

STRAY VOLTAGE TESTS

The stray voltage tests are performed using a Triplett Meter Model-630-NA. The circuits checked are the two output connectors from each EBW F/U. Each connector contains two pins (A&B) with pin B being the positive signal from the output electrode of the gap tube and pin A being the circuit return (see Figure 3). The stray voltage checks and the resistance checks are performed from pin-to-pin and pin-to-case.

The specification values for allowable stray voltage and circuit resistance are as follows:

STRAY VOLTAGE*	PINS	RESISTANCE**
50 mvac or mvdc	A to B	3000 ± 300 ohms
50 mvac or mvdc	A to Case	100 ± 10 ohms
50 mvac or mvdc	B to Case	2900 + 200 ohms
50 mvac or mvdc	Case to Ground	less than 0.3 ohms

Since the incentive for examining this operation is personnel safety and the possibility of relaxing clearance requirements during S&A device ordnance connection, the author questioned whether or not a voltage fault in the trigger circuit would be detected by the stray voltage check of the output circuit. This question along with how a stray voltage (pulse or continuous) would affect the output circuitry was directed at J. Stulting (R-ASTR-EAS) of MSFC. The following test data from laboratory tests on a test EBW F/U was made available to the author:

---

*Extracted from Reference 13.

**Extracted from Reference 9.

STRAY VOLTAGE AND RESISTANCE CHECKS WITH CONTINUOUS 30 VDC APPLIED TO THE TRIGGER CIRCUIT

STRAY VOLTAGE*		PINS	RESISTANCE
0 mvdc	0 mvac	A to B	3000 ohms
27 mvdc	100 mvac	A to Case	92 or 108 ohms**
20 mvdc	100 mvac	B to Case	2800 or 3000 ohms**

Using a Tektronics 555 oscilloscope, the stray voltage checks were repeated:

STRAY VOLTAGE	PINS
1.7 volt spike @4 ms intervals	A to B
2.6 volt spike @3 ms intervals	A to Case
2.6 volt spike @4 ms intervals	B to Case

A continuous voltage applied to the trigger circuit either prior to or simultaneous with the EBW F/U charge command (ECO) would result in the failure of the EBW F/U to charge. This is due to a circuit (see Figure 3) within the F/U which is designed to bias-off the charge circuit (removes the F/U drain from the A/B battery during output capacitor discharge) when the Destruct command is received. A trigger input received while the F/U is in process of charging (see Figure 4 - Typical EBW F/U charge curve) would discharge the output capacitor into the EBW detonator if the output capacitor had built up sufficient voltage to break down the gap tube. As noted in Addendums II and III, the gap tube will break down between 600-1200 vdc but the ALL FIRE criteria for the EBW detonator is 1800 vdc. Voltages high enough to break down the gap tube but not high enough to detonate the PETN or RDX within the detonator will most likely cause it to "dud".

A pulsed stray voltage fault on the trigger circuit either prior to, simultaneous with, or subsequent to the charge command (but prior to adequate ALL FIRE charge) will probably negate proper detonation. Since the trigger

---

*A Triplett Meter Model-630-NA was used for this test. It was reported that the meter sensitivity and response was not sufficient to detect trigger faults when a pulsed input similar to that expected in flight (30 vdc, 20 ms duration every 200 ms) was applied.

**Dependent upon polarity of the meter leads.

input which is normally expected out of the decoder is present for only 20 ms in every 200 ms, the charge circuit would be allowed to charge for the other 180 ms. The following laboratory tests indicate how long the output capacitor takes to charge sufficiently to break down the gap tube with a simulated pulsed trigger fault:

A. Test Configuration

In all four cases, 30 vdc was applied continuously to the charge circuit at T_o.* Simultaneously, a control switch was closed to the trigger circuit applying a square wave input (30 vdc, duration--≈32 ms, frequency--≈every 165 ms). Since the square wave input voltage could be at any stage of its waveform when the switch was closed, the voltages weren't actually applied simultaneously. The PULSE TIME column indicates when the leading edge of the trigger pulse was applied to the trigger input with respect to T_o. The test load was varied as indicated. A Tektronics 555 oscilloscope was used for all test measurements.

B. Test Cases

1. Load - carbon path type squib

Data -

PULSE	PULSE TIME	OUTPUT CAPACITOR VOLTS (vdc)	REMARKS
First	-15 ms**	0	
Second	+150 ms	1100 → 1000	***
Third	+315 ms	1600 → 0	Gap tube breakdown

Note: Subsequent to the initial gap tube breakdown, the circuit recharges sufficiently to break down the gap with every other trigger pulse.

---

*Time zero

**Circuit to trigger was closed 15 ms prior to the end of a square wave pulse.

***The apparent slight discharge is a result of the output capacitor discharging through the bleeder network while the charge circuit is biased-off.

2. Load - Same as Case #1

Data -

PULSE	PULSE TIME	OUTPUT CAPACITOR VOLTS (vdc)	REMARKS
First	+70 ms	750 → 650	*
Second	+235 ms	1350 → 0	Gap tube breakdown

Note: Output circuit discharges every 2nd pulse similar to Case #1.

3. Load - Output shorted

Data -

PULSE	PULSE TIME	OUTPUT CAPACITOR VOLTS (vdc)	REMARKS
First	+120 ms	1050 → 950	*
Second	+285 ms	1500 → 0	Gap tube breakdown

Note: Output circuit discharges every 2nd pulse similar to Case 1.

4. Load - Open circuit

Data -

PULSE	PULSE TIME	OUTPUT CAPACITOR VOLTS (vdc)	REMARKS
First	+60 ms	650 → 550	*
Second	+225 ms	1250 → 600	Gap tube breakdown
Third	+390 ms	1250 → 500	Gap tube breakdown

Note: Output circuit discharges every trigger pulse after the initial gap tube breakdown but does not discharge to zero volts due to the open load circuit.

---

*The apparent slight discharge is a result of the output capacitor discharging through the bleeder network while the charge circuit is biased-off.

The foregoing discussions and test data allow the following conclusions to be drawn:

1. A continuous voltage fault on the EBW F/U trigger circuit would be detectable using the Triplett Meter Model-630-NA even though the resistance readings are within specification (although offset) and the voltage readings are not grossly out of specification.

2. A pulsed input fault (similar in waveform to the decoder output) on the EBW F/U trigger circuit would not be detectable using the Triplett Meter due to the inherent meter sensitivity/response time.

3. An oscilloscope (or possibly a more sensitive voltohmeter) would more positively detect the fault of item 1 and would allow detection of the fault of item 2.

4. A continuously applied trigger signal prior to sufficient output capacitor charge would negate gap tube breakdown. A trigger signal applied after the output capacitor reached sufficient magnitude to breakdown the gap tube but below the EBW detonator ALL FIRE value could result in dudding rather than detonation of the EBW detonator.

5. Pulse inputs applied to the trigger circuit prior to the output capacitor reaching the ALL FIRE (1800 vdc) value could also result in dudding rather than detonation. The four test cases revealed gap tube breakdown at 1600, 1350, 1500, and 1250 volts DC, respectively.

6. Admittedly, a fault in the trigger circuit might not present an immediate hazard to the personnel connecting the circuit to the EBW detonator but an undetected fault in the trigger input circuit could make the PDS more susceptible to a subsequent single failure as well as prevent the PDS from performing properly (if required) in flight.

7. The stray voltage test (with a more sensitive measurement device) is perhaps the <u>only</u> adequate means of detecting a trigger circuit failure since the PD Block function prevents the ESE and/or telemetry from monitoring downstream of the K4-1 contacts in the RSS controller (see Figure 2).

8. It should also be stressed that a failure (which could apply power to the trigger circuit) with power removed from the decoder/receiver and EBW F/U is extremely remote and even difficult to imagine. Because of this, the author later concludes (in section 9.0) that the stray voltage checks are adequate to protect the ordnance crews during connection but this should not be interpreted as reason enough not to consider the data presented above.

TABLE 3

ABBREVIATIONS

AAA	Apollo Access Arm
A/B	Airborne
AC	Alternating current
ANT	Antenna
AUTO	Automatic
BATT	Battery
C	Common, Centigrade
cal	Calorie
CDDT	Countdown Demonstration Test
CDF	Confined Detonating Fuse
CDWG	Countdown Working Group
CKT	Circuit
cm	Centimeter
CMD	Command
CSM	Command and Service Module
DAC	Douglas Aircraft Company
DC	Direct Current
DEST	Destruct
DISP	Dispersion
DRSCR	Digital Range Safety Command Reveiver
EBW	Exploding Bridgewire
ECO	Engine Cutoff
ENG	Engine
ESE	Electrical Support Equipment
ETR	Eastern Test Range
EXT	External
F	Farad, Farenheit
FTS	Flight Termination System
F/U	Firing Unit

Table 3

GBI	Grand Bahama Island
gm	gram
GND	Ground
gr	grain
GTK	Grand Turk
Hg	Mercury
INT	Internal
IU	Instrument Unit
K	Relay Designator
kg	Kilogram
LC	Launch Complex
LCC	Launch Control Center
LDI	LCC Computer Digital Input
LDO	LCC Computer Digital Output
LM	Lunar Module
LSC	Linear Shaped Charge
LUT	Launch Umbilical Tower
LV	Launch Vehicle
LVO	Launch Vehicle Operations
MDI	LUT Computer Digital Input
MDO	LUT Computer Digital Output
ms	millisecond
MSS	Mobile Service Structure
mv	millivolt
OATS	Overall Test Set
OSC	Oscillator
PAFB	Patrick Air Force Base
PD	Propellant Dispersion
PDS	Propellant Dispersion System
PETN	pentaerythyrite tetranitrate
PROP	Propellant

Table 3

PWR	Power
R	Return
<u>R</u>	Reset
RCVR	Receiver
RDX	cyclotrimethylene trinitramine
RECT	Rectifier
RF	Radio Frequency
RSO	Range Safety Officer
RSS	Range Safety System
<u>S</u>	Set
SC	Spacecraft
SCO	Spacecraft Operations
S&A	Safety and Arming
SV	Space Vehicle
Syst	System
TCS	Terminal Count Sequencer
TD	Time Delay
UHF	Ultra-High Frequency
vac	volts alternating current
vdc	volts direct current
VOLT	Voltage
XFER	Transfer

BELLCOMM, INC.

Subject: Range Safety System Operations During Saturn V Launch Countdowns Case 320

From: G. J. McPherson, Jr.

DISTRIBUTION LIST

NASA Headquarters

Messrs. R. O. Aller - MAO
P. J. Bayer - MAO
L. E. Day - MAT
G. H. Hage - MA-A
J. K. Holcomb - MAO
T. A. Keegan - MA-2
C. H. King - MAT
E. W. Land - MAO
C. M. Lee - MA
C. W. McGuire - MY
T. H. McMullen - MA
R. V. Murad - MAT
S. C. Phillips - MA
W. C. Schneider - MA
J. B. Skaggs - MAP
F. E. Stout - MAO
G. C. White - MAR

Kennedy Space Center

Messrs. D. D. Buchanan - DE-KEM
W. T. Clearman, Jr. - AP-SAT
A. Demco - LV-INS-11
P. C. Donnelly - LO-OPN
C. W. Dowling - LV-ENG
A. G. Griffin - LO-PLN-3
A. H. Moore - TS-TSM
R. E. Moser - LO-PLN
C. B. Netherton - LO-PLN-3
D. L. Nichols - LS-TOM-1
T. L. Oglesby - LV-TOM-3
E. M. Sestile - LV-TOM-2
R. E. Woods - SF-OPN
J. C. Wootton - AP-SYS

Manned Spacecraft Center

Messrs. C. H. Bolender - PA
K. S. Kleinknecht - PA
O. E. Maynard - PD

Marshall Space Flight Center

Messrs. L. B. Bell, Jr. - I-V-E
L. A. Conway - I-V-E
H. J. Fichtner - R-ASTR-E
J. B. Stulting - R-ASTR-EAS

DISTRIBUTION (Cont'd)

Air Force Eastern Test Range
(Patrick Air Force Base)
Capt. J. C. Along - Missile Safety
Lt. Col. D. W. Rabey - Range Safety
Maj. R. Taylor - Range Safety

Douglas Aircraft Company
Mr. D. A. Roesch - VK-20

North American Rockwell
Messrs. F. J. Powell - ZK49
M. F. Williams - ZK49

Boeing Atlantic Test Center
Messrs. H. Ilisko - MSO 2133
D. B. Weinberg - MSO 2031

Grumman Aircraft & Engineering Corporation
Mr. E. W. Smith, Jr. - GAEC-300-22

Bellcomm, Inc.

Messrs. C. Bidgood
A. P. Boysen, Jr.
J. J. Hibbert
J. A. Llewellyn
J. Z. Menard
T. L. Powers
J. T. Raleigh
W. Strack
G. B. Troussoff
R. L. Wagner
Central Files
Department 2032
Department 1023
Library

ABSTRACT ONLY TO
Bellcomm, Inc.

Messrs. D. A. Chisholm
D. R. Hagner
B. T. Howard
I. M. Ross
J. W. Timko